• **Adaptive Control** = “controller with adjustable parameters and a mechanism for adjusting the parameters” (Astrom & Wittenmark, 1995)
Implication: Process Variations

• Simple Example #1

\[ G_1(s) = \frac{1}{(s+1)(s+a)} \]

\[ a = [-0.01, 0, 0.01] \]
Bode Plots – Example #1
Implication: 
Process Variations

• Simple Example #2

\[
G_1(s) = \frac{400(1 - bs)}{(s + 1)(s + 20)(1 + bs)}
\]

\[
b = [0, 0.015, 0.03]
\]
Bode Plots – Example #2

(a) Magnitude

(b) Magnitude

Frequency [rad/s]

Phase [deg]

T = 0, 0.015, 0.03

T = 0, 0.03

T = 0, 0.015

T = 0, 0.03
Approaches to Adaptive Control

- Gain Scheduling
- Model-Reference Adaptive Control
- Self-Tuning Regulator
- Dual Control
Gain Scheduling Control

- Exploit measurements to predict variations
- Update parameters (e.g., gain) on-line
- Can be implemented as look-up table
Model Reference Adaptive System (MRAS)

- Performance specifications given as reference model
- Model error drives parameter update
Self-Tuning Regulator (STR)

- Process parameter update scheme
- Tunes parameters to obtain desired closed-loop response
Dual Control

- Nonlinear stochastic control theory
- Controller accounts for competing objectives of identification and regulation
Adaptive vs. Gain Scheduling

Process dynamics

- Varying
  - Use a controller with varying parameters
    - Unpredictable variations
      - Use an adaptive controller
    - Predictable variations
      - Use gain scheduling
  - Constant
    - Use a controller with constant parameters